THE COMMAND AND DATA MANAGEMENT SYSTEM OF SPACELAB[*]

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ABSTRACT

This paper describes the Spacelab command and data management system and its support capabilities for various types of experiments in terms of data processing, display, recording, and multiplexing.

INTRODUCTION

The European Spacelab is one of the several parts of the Space Transportation System. When carried into space by the Orbiter, it provides features and services for the user community working in space research and space applications. Like the Space Shuttle, Spacelab is designed to be reflown many times. Its purpose is to extend the Space Shuttle capability in a manner suitable for the user community. With the Space Shuttle, it can be regarded as a short-stay space station which can stay in space for a duration of a nominal 7 and a maximum of 30 days.

Spacelab is designed as a general-purpose laboratory having features and services similar to those provided on the ground. These services include power conditioning and distribution, environmental control, command and data management, and system software.

In order to meet the requirements of users, Spacelab can be assembled from several modular units to meet a particular mission requirement. The overall set of Spacelab configurations is fully described in Reference 2.

When flown in the orbiter, the Spacelab receives support services in the form of electrical power and energy, heat dissipation, and telecommunications.

The overall data path is shown in Figure 1. Data are generated by the payload either accommodated in the module or on the pallets of Spacelab. These data are then acquired

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by the Spacelab data management system and multiplexed in low-rate housekeeping and high-rate scientific data streams for transmission by the orbiter. This orbiter transmission is controlled by the orbiter crew through the orbiter avionics system. The orbiter can communicate at Ku-band with the Tracking and Data Relay Satellite System (TDRSS). All ground communication with the orbiter/Spacelab pass through the one ground station of the TDRSS. The overall coverage is not 100 percent. Due to Earth geometry and beam blockage by the orbiter and Spacelab payload structure, the coverage in Earth-orbital space is between 50 and 85 percent over a 24-hour period. To bridge mission periods with no downlink capability, a digital recorder is included in Spacelab to record payload data with provisions to interleave its recorded data into the data system when communication with ground is restored.

The TDRSS ground station communicates the payload data (as opposed to the orbiter/Spacelab operating data) to the payload operations control center (POCC), with the rest of the data being communicated to the mission control center (MCC). In the POCC, ground-based scientific personnel will have a direct involvement in the flight operation. Because of the high data rates, the POCC will also require further communication links to other remote payload centers either by land lines or by satellite links.

The overall telecommunications block diagram is shown in Figure 2 and is taken from Reference 3. This shows the command and data acquisition paths to and from the user and the ground. It will be seen that commands to the payload/experiment can be generated by the:

- POCC
- MCC
- Orbiter avionics and/or crew
- Spacelab avionics and/or crew
- Payload/experiment itself

Similarly, data can be acquired by each of the above. Various data paths exist and are used for different purposes.

The uplink command capability consists of 2 kbits/s from the MCC to the Spacelab avionics via the TDRSS and the orbiter communications and avionics systems.

The downlink is either through the Spacelab/orbiter telemetry interface (which is limited to 64 kbits/s) or the payload high data rate telemetry downlink which can be operated up to a maximum of 50 Mbits/s.

As a service to the user, Spacelab is able to distribute uplink commands throughout the payload area and also issue commands at a specified time or when certain required conditions exist. Similarly, a capability is provided which can acquire data in the low- and high-rate data streams from the payload area. This is accomplished by the Command and Data Management Subsystem (CDMS) of Spacelab. The overall block diagram of the CDMS is shown in Figure 3. It will be seen that the CDMS not only provides the above services, but also is able to allow the input, display, and manipulation of data as well.

The on-board units of the CDMS system are given in Table I with their basic functions. These units are shown in Figure 4.

The CDMS also includes a voice intercommunication assembly and a closed-circuit television extension of the orbiter subsystems, which are described in Reference 2.

THE COMMAND AND DATA MANAGEMENT SUBSYSTEM TASKS

The CDMS consists of a data processing assembly (DPA) for low-rate data acquisition and command distribution and a high-rate data assembly (HRDA) for high-rate data acquisition.

The DPA contains experiment and subsystem parts. The subsystem part is for subsystem operation and is independent of the experiment part. This separation is to ease payload integration and to prevent interference among the experiments and the subsystems. Each part of the DPA consists of a computer (3.2×10^5 typical operations per second, 64K 16 bit words core memory), an IOU unit (6 data bus couplers each with a micro-machine) and a digital data bus (1 Mbit/s) routed through Spacelab with standard interface units (RAU's). Peripherals shared between both parts of the DPA are three keyboards and displays, and a mass memory unit (8×10^6 words). The DPA's role is to acquire data and to distribute timing and commands with the data bus rate of 1 Mbit/s and to interface with the orbiter-payload multiplexer/demultiplexers (MDM's), the PCM master unit (PMU), and the master timing unit (MTU).

The HRDA consists of a high-rate multiplexer, a high-data-rate recorder (HDRR) and a highrate demultiplexer on the ground. The HRDA's role is to acquire data directly from the users and to time-division multiplex these data into a composite data stream of up to 48 Mbits/s. This data stream is interfaced with the orbiter Ku-band communication system and subsequently transmitted to the ground via the TDRSS. On the ground, the demultiplexer is used to derive the original user inputs to the multiplexer. In the multiplexing operation, some low-speed data acquired by the DPA can be merged into the data stream. The multiplexer also adds digitized voice and timing data to the bit stream as required.

The HDRR has been added to the system to act as a storage buffer to cover periods during which TDRSS transmission is interrupted. This recorder can record 1 to 32 Mbits/s for a period of 20 min to over 10 hr. This storage buffer is intended to be emptied during the next TDRSS transmission period by the recorded data being interleaved and multiplexed with new real-time user data. The user may also record experiment data for on-board storage. In the case where the mission does not demand a rate of 32 Mbits/s and can be accommodated by a 1 Mbit/s rate, the payload recorder of the orbiter is used in place of the HDRR. This also has to be the case in the pallet-only mode since the HDRR can only be flown in the module.

The operational software required to run the DPA and control the HRDA is supplied with the subsystem DPA. This operating system is called SCOS (subsystem computer operating system) and controls all the units described above. Since during launch and entry all the CDMS are switched off, the CDMS has to be activated/deactivated from the orbiter. This is accomplished by a manual activation/deactivation sequence which allows the subsystem DPA to be controlled via the orbiter payload MDM's. When the subsystem DPA is operating, it then has control over the experiment DPA, the HRDA, and other parts of Spacelab. The operational software for the experiment DPA is called ECOS and contains special functions for payload operation. Both these operating systems provide support to applications programs written in assembler. Above this, SCOS supports application programs written in HAL/S and ECOS supports them in FORTRAN.

As has been explained, the CDMS is divided into two areas for subsystems and experiments so that payload integration is eased and interference is reduced. In the frequency domain, it has also been necessary to design the DPA for low-speed command and data acquisition and the HRDA for high-speed data acquisition. The two assemblies will now be described with regard to data communications, crew/orbiter and payload interfaces, and hardware and software techniques.

LOW RATE COMMAND AND DATA ACQUISITION

The CDMS low-frequency communications involve data transfer within the DPA, between the DPA and the orbiter, and between the DPA and the user. As has already been explained, the DPA is divided into two similar parts, subsystem and experiment; but for simplicity, only the experiment portion will be discussed, since the subsystem portion has no user interface and is concerned with the management of the Spacelab subsystems.

Internal Operation

The internal data communications within the DPA permit the computer to dialog with its peripherals:

- Remote acquisition units (RAU’s)—which handle the user interface
- high rate multiplexer (HRM)—which accepts DPA data for incorporation into the high speed downlink
- Data display systems (DDS’s)—which provide a crew interface with the DPA
- Mass memory unit (MMU)—which contains computer program memory loads and display data

Note that the DDS’s and the MMU are shared with the subsystem DPA. The overall DPA configuration is shown in Figure 5.

Internal data are transferred on redundant half duplex 1 Mbit/s serial data buses which are controlled by the computer and managed by the I/O unit (IOU). Data are transferred over the buses in a Manchester-II format in 16-bit words preceded by a 3-bit time, non-Manchester synchronization pattern and followed by an odd parity bit.

The peripherals are controlled by instructions transferred via the relevant data bus from an IOU coupler. Each coupler consists of a discrete component micro-machine having its operation defined by instructions stored in a 512 word read only memory. Connection between the coupler micro-machine and the serial data bus is effected by a bus interface unit (BIU), which converts outgoing messages into the previously described Manchester format and incoming messages to standard TTL logic levels. The BIU is also constructed using a micro-machine, and performs a number of error checks on the incoming data.

This data transmission method is used for communication between the CPU memory and the RAU, HRM, DDS, and MMU.

Orbiter Interface

Three communications paths are provided for data transfer between the DPA and the orbiter (see Figure 5). Serial data buses are again used which are controlled by the orbiter, supported by the IOU. These paths are between the DPA and Orbiter MDM’s, which permits a dialog between the CDMS computers and the orbiter general purpose computers (GPC’s); the DPA and the orbiter PMU for the transfer of engineering telemetry data via the orbiter to the ground; and with the orbiter MTU and the DPA, which provides time reference for the CDMS and the users.

Payload Interface

The DPA interface to payload hardware is provided by the RAU. Its capabilities, which are under software control, are as follows:

- 64 ON/OFF command outputs. The ON state outputs 20 mA at approximately 5 V.
- 128 flexible inputs arranged in blocks of 16. When acquired as discretes (one to eight blocks may be transferred as one to eight words). When acquired as 8 bit resolution analog inputs, channel pairs may be transferred as single words (single mode) or 1 to 8 blocks of 16 channels may be transferred as 8 to 64 words (scanning mode).
- 4 serial output channels providing 1 to 32 NRZ-formatted words, including associated burst clock.
- 4 serial input channels acquiring 1 to 32 NRZ-formatted words on user request with concurrent IOU command.
- 4 User time clocks (UTC's) and associated 4 pulse/s UTC resets. The clock is 1024 kHz referenced to the orbiter MTU.

The ON/OFF commands are used to control user hardware, and they may be individually set or reset by asynchronous commands from the DPA. The operating system also provides facilities for pulsing these outputs. For some applications where the DPA has to communicate with an "intelligent experiment" containing a dedicated experiment processor (DEP), synchronous data transfer on serial input and output channels may be required. In this case a discrete ON/OFF command channel may be used to indicate to the DEP the phase of the periodic input/output loop (PIOL) by the insertion of a pair of triplets at an appropriate position in its tables.

Flexible inputs may be read into the DPA at sample rates from 1 to 100 samples/s by the insertion of appropriate triplets in the PIOL tables. The third word of each triplet executed by the IOU coupler is an instruction that is sent to the RAU's, but only recognized by the specific unit addressed. This word defines to the RAU the channels to be acquired and mode, analog or discrete. The maximum total acquisition rate for flexible input data is approximately 500 kbits/s.

Serial output channels provide the means for transferring large amounts of data to a user. These can be used for initial program load of a DEP or the results of the processing by the DPA of data acquired from the DEP, the orbiter, or another experiment. The transfer may be synchronous or asynchronous and consists of messages of 1 to 32 words. Except for very simple cases, the first word will contain information on the nature and magnitude of the message. The maximum practical data transfer rate for all users is approximately 100 kbits/s.

Serial input channels provide the means for acquiring digital data from users. On user request, one to 32 words may be transferred by the next arriving IOU serial input command. Clearly, synchronization of user data availability with the PIOL acquisition is a problem that can be solved either by "oversampling" or by synchronizing the DEP activities with the PIOL as outlined above. The maximum practical data transfer rate for all users is approximately 50 kbits/s.

The UTC is continuously available from experiment RAU's whenever the experiment module is ON. It consists of a precision 1024-kHz clock derived from the orbiter MTU and reset pulses occurring at 4/s. After initialization either with GMT from a serial output channel or by an ON/OFF command, the user can maintain absolute or relative time within his experiment for tagging his data as required. In the event of IOU time coupler or time-bus failure, the accuracy of the 1024 kHz will be degraded and the UTC reset pulses will cease.

Hardware/Software Techniques

Synchronous and asynchronous communication between the DPA computer and the user via the data bus and RAU are managed by the PIOL. As has been outlined before, the PIOL consists of command tables assembled at system generation time which define a sequence of RAU input and output activities allocated over 100 10 ms time slots. In each time slot, all but one command is for a synchronous transaction. The remaining (last) command is a dummy, normally skipped, which can be loaded with an asynchronous command specifically generated in response to a user application program request. For input data, the result of this asynchronous transaction is passed to the requesting program, whereas synchronously acquired data arrive in predefined locations in the PIOL table with no specific alert to a data user. Execution of PIOL 10 ms segments is initiated by the CPU in response to the 10 ms interrupts generated in the time coupler by the decoding of the MTU 100 pulse/s IRIG-B GMT input, and proceeds under RAU coupler control until an "error" or "end of work" is signaled to the CPU by the general IOU interrupt.

This method of data acquisition is very efficient and has the additional benefit that data obtained by the PIOL may be output via the PMU for downlink simply by having an appropriate overlap of the PIOL table and the telemetry buffer in core. Since the multiplexer also has an interface with the RAU bus and responds to a subset of the RAU instruction repertoire, it is possible to reformat data acquired from RAU's and output them to the multiplexer simply by the inclusion of suitable triplets in the PIOL. Thus the DPA can operate as low-speed sub-multiplexer with no significant CPU overhead. Output rates to the multiplexer of up to 50 kbits/s are feasible.

The DPA has three identical CIMSA 125 MS computers as part of the assembly. Two of these computers are used in the subsystem and experiment parts of the assembly. The third is used as a back-up, primarily for the subsystem computer. This redundancy is continued through the assembly in the two IOU's, each IOU having dual redundant functions. Each IOU can drive either of two data buses that are connected to each RAU of the subsystem or experiment assemblies. The data display systems are also redundantly connected to both the subsystem and experiment IOU. The overall reliability of the system is high (0.95) in the module mode and a little less (0.93) in the pallet-only mode, the weak point being that of the one MMU. The original use of this mass memory was to store all basic subsystem software in the unlikely case of a failure in the initial load of the subsystem computer after arrival in orbit. Since the mass memory can store over 120 complete 64K core loads, it can also be used to support the experiment computer. This has resulted in the MMU tending to be used as an on-line device rather than a back-up device.

The data display system introduces a new dimension into space technology in that the data display unit (DDU) has a tricolor (green, yellow, red), penetration-type, cathode ray tube with a 12-in. diagonal screen.

The user is expected to call up various displays via the keyboard into the DDU screen for experiment evaluation and control. Display formats that are stored within the DPA are supported by SCOS and ECOS as appropriate.

Much has been said about the software of the CDMS. The two operating systems, SCOS and ECOS, will be fully developed with the hardware. Much thought was given as to how the user and operator of Spacelab would develop application programs for the CDMS and then check out and validate hardware/software operation. This process of software checkout was one of the evaluation criteria when the computer was selected. It was required that the on-board computer should have a comparable ground computer which was, in most respects, common (especially in real-time behavior) with the on-board machine, but of course with the added advantage of having a much larger set of peripherals and versatility to produce software.

The ground machine for the 125 MS is the MITRA 125S. These machines have identical instruction sets, operating speeds on instruction and instruction-mix level and input/output architecture. The MITRA 125S has been used in the early stages of hardware/software development in the Spacelab program. It has been shown on the engineering model of Spacelab the the final insertion of the on-board machine into the DPA can be done with few problems.

By this process of commonality, it is planned that users and complete payloads will be checked out with the use of ground support equipment which will use the MITRA 125S and that cross-product software on host computers will only be used in the early stage of application software development. By giving the user the chance to accurately simulate the real-time on-board computer with the use of a ground equivalent, the time taken in final integration will be reduced over the case where no such common computer existed.

HIGH RATE DATA ACQUISITION

The CDMS high-frequency communications involve data transfer within HRDA from the user to the orbiter. The performance of the HRDA has to be compatible with the constraints of the Ku-band signal processor (KUSP), the orbiter, and the TDRSS. The combination of the orbiter/ TDRSS communication capability for Spacelab is an ability to handle simultaneously the following:

- One channel in the range 16 kbits/s to 2 Mbits/s (NRZ-L, M, or S) or 16 kbits/s to 1.024 Mbits/s (biphase L, M, or S)
- One channel of either 16 kbits/s to 4 Mbits/s (NRZ-L, M, S) or 2 Mbits/s to 50 Mbits/s (NRZ-L, M, S) or one analog/video channel.

It is the purpose of the HRDA to make this capability available to many users in Spacelab.

The HDRA comprises the following equipment:

On-Board:

- The HRM to time-multiplex the input data and to perform the routing of the composite output data stream to one of the two recorders and/or one of the three KUSP digital inputs.
- The HDRR to store data at rates up to 32 Mbits/s during mission periods without (or degraded) downlink capability.
- The payload recorder (orbiter equipment) to store data rates up to 1 Mbit/s during mission periods without (or degraded) downlink capability where the HDRR is not required or not flown.

On-Ground

- The HRDM to demultiplex the composite data stream to recover on ground the same channels as presented at the HRM inputs on board.

Data Paths and Routing in Multiplexer

The overall data routing capabilities of the multiplexer are shown in Figure 6. In particular, the HRM is capable of performing the following routing configurations:

- Multiplexed experiment data routed to one of the 3 KUSP inputs for real-time transmission
- Multiplexed experiment data recorded on one of the 2 recorders (simultaneously with real time transmission, if required)
- HDRR output routed directly to one KUSP input. Multiplexed data stream switched-off or routed to another KUSP input
- Same as 3, but functions of HDRR and payload recorder interchanged
- Direct access channel routed to the 2-50 Mbit/s KUSP input. Multiplexed data stream switched-off or routed to another KUSP input or recorded on one of the 2 recorders
- Direct access channel routed to the HDRR and recorded. Multiplexed data transmitted in real time or recorded on payload recorder

The HRM routing modes are commanded by the subsystem computer via the subsystem data bus and the BIU interface dependent on downlink availability, Ku-band signal processor operational mode, and multiplexed data rate.

Multiplexing Concept

The HRM collects serial data from different sources, performs time-division multiplexing based on 16-bit time intervals and, finally, delivers an output of one serial data stream containing all the input data (Reference 4).

The main characteristic of the concept employed is the capability to accept serial data that are completely asynchronous with respect to the HRM internal clock. The decoupling of the input clock from the HRM internal clock is performed by means of 4 x 16-bit input buffers.

The user clocks his data into a 16-bit shift register; then—after 16 bits—the content will be loaded into the 4 x 16 buffer.

In a sequence determined by the format table, the format controller fetches one 16-bit word out of the input buffer and transfers it to the output register, where it will be serialized. In the case of an empty input buffer, a fill word is introduced, which can be identified as such by means of the fill identification as a part of the frame overhead. During demultiplexing on ground, the fill words are automatically suppressed.

High Data Rate Recorder Design

The principal function of the HDRR is to provide for intermediate recording of experimental data in the following cases:

- When the orbiter-TDRSS-ground link is not available
- When the required channel capacity is not available
- When on-board storage of raw experiment data is required

In this case, the tape change capability can be used during flight.

The HDRR and HRM form an integrated system. Both are controlled by the subsystem computer in a coordinated manner. The data display system is the control and monitoring interface with the user. The experiment interfaces with the HDRR are via the HRM only.

During record and reproduce, the HDRR is externally synchronized by the HRM clock except in the direct access mode when the experiment supplies the record clock. Recording can be done in parallel to the real-time transmission to the ground. In the reproduce mode, the buffered data can be interleaved in the HRM with the real-time data stream.

Data recording for on-board storage without transmission to the ground is only allowed in periods when the HDRR is not used as a buffer device in the ground link.

Operational control of the HDRR is effected via discrete commands from a subsystem RAU. However, sufficient local controls are provided on the HDRR to allow tape change and to inhibit normal control during this operation. In addition to monitoring the command status and the recorder housekeeping signals, the subsystem RAU also receives a parallel 8-bit word representing the amount of tape used. This information is interpreted by software to represent “tape used” and “remaining tape” for display on the DDU.

The design of the HDRR is based on a technology previously applied for satellite recorders requiring data rates in the 1 to 5 Mbit/s domain. In order to achieve the 1 to 32 Mbits/s record/reproduce range, with variable speed and record times, a low bit error rate, combined with an in-flight tape change capability and very low power consumption, several technological thresholds in spaceborne recorder design had to be pushed forward.

High Rate Demultiplexer Design

The decommutation of the data stream received on ground via the TDRSS link is performed by the HRDM shown in Figure 7. The HRDM input circuit receives a serial data input from the ground station bit synchronizer. The link is composed of three lines (data, clock, and bit synchronizer lock status). As long as the lock status is not true, input data are not considered valid. The HRDM is synchronized on the input clock and can operate at any rate up to 50 Mbits/s.

The format generator stores up to 16 formats in programmable, read-only memories plus two formats in random access memories (RAM's). Each format consists of 768 5-bit words. Each word represents the channel address of the corresponding word in the format. One frame of the HRDM input data consists of 96 words, so that one format repeats every eight frames. The two RAM's can be loaded from a ground computer or paper tape reader.

In the BCH decoder and data buffer, the data are buffered line by line and the fill identification word decoded. Each line is then decommutated; fill words are removed; and the detected data are sent to the appropriate output channel buffer.

Orbiter Interface

The ≤ 2 Mbit/s and ≤ 4 Mbit/s links from the HRM to the KUSP are realized with differential drivers/receivers and use a 75 Ω twisted, shielded pair (TSP). Data are transmitted without clock. The design is state-of-the-art and has posed no technical problems.

The interface requirement for the ≤ 50 Mbit/s link has imposed many technical problems on the deisgn of the HRM.

The link requires the following performance:

- Clock/data phase off-set ≤ 2 ns
- Clock duty cycle (including asymmetry and jitter) in the range 50% ±5% of bit period. (This is 10 ±1 ns at 50 Mbits/s.)
- Rise and fall times ≤ 3.5 ns
- Signal-to-noise ratio better than 35 dB (200 MHz bandwidth)
- The bit transition density at least 64 transitions in 512 bits with a maximum separation of 64 bits between successive transitions

Payload Interface

The user interface is implemented as a "two-wire" system. The HRM input requires data and clock for each channel. The cable used between the experiment and the multiplexer is a 125 Ω TPS. The signal level used is 0.5 V peak to peak to 1.5 V peak to peak. The requirements on the output drivers of the experiments are very critical at rates of 16 Mbits/s to 50 Mbits/s.

The most critical parameters are:

- Data/clock phase offset ±10% of bit period
- Clock duty cycle 50% ±10%/ of bit period
- Data/clock jitter ±10% of bit period

Ground interface

The demultiplexing on the ground is performed by the HRDM. Any user requiring real-time data on the ground will have to interface to the HRDM. The interface is realized with ECL compatible output drivers.

The flight hardware HRM and ground HRDM, as well as the KUSP/TDRSS combination, are designed as a transparent link; that is, data that are entered into the HRM on-board appear at the output of the HRDM.

Hardware/Software Techniques

The HRM is connected with the Spacelab CDMS subsystem and experiment computers by means of the subsystem and experiment data buses as shown in Figure 8. Data from both computers to the HRM are transferred in blocks of 16 bit words. Control, monitoring, and configuring functions of the HRM are performed by the subsystem computer only.

The data transfer link from the subsystem computer has been introduced to allow any subsystem housekeeping data to be introduced into the HRM composite bit stream for assessment on ground.

The experiment-computer-to-HRM link provides the possibility to use the experiment computer as a pre-multiplexer. Data required via RAU's are formatted within the computer and sent to the HRM. This link is constrained by the data bus performance and the computer software.

Mechanization of data transfers is realized by the (PIOL) software package. This package acquires and transmits data according to an off-line prepared input/output list. The upper limit for the actual data transfer is on the order of 25 kbits/s.

Data are organized in blocks of up to 32 words of 16 bits. Block lengths and spacing between blocks define the frequency share for this channel in the HRM. The worst case is a channel frequency of 0.8 Mbits/s for “random” data transfers.

The subsystem computer link only provides for a control and monitoring interface.

PROGRESS TO DATE AND THE FUTURE

Spacelab, which has completed development and is now entering the system-level verification phase, represents Europe’s first participation in a major manned space project. The work is being performed under contract from the European Space Agency (ESA)/Paris, France, with the Spacelab Project Management Office at the European Space Research and Technology Centre, ESTEC, Noordwijk, The Netherlands. A multi-national consortium of co-contractors and subcontractors, under the leadership of the prime contractor VFW-Fokker/ERNO-Bremen, Germany, operate the contract. The CDMS is being managed by MATRA Espace-Velizy, France. The various subcontractors to MATRA for the hardware and the unit development status are given in Reference 1.

The overall contract price for this CDMS is on the order of 40 million dollars. The present contract began in 1974 and is planned to end with the completion of the second Spacelab flight.

Today, the system testing and integration at ERNO is well underway. The electronic systems integration (ESI) model, tests of which have been completed, was assembled from elegant breadboard models of the electrical subsystem hardware items. The engineering model (EM) tests are almost complete and have shown that the planned performance of the various units is being demonstrated.

The flight model (FM) tests have begun, and delivery of the first assembly (long module and pallets) to NASA is planned in 1980. Part of this assembly will be used for the first Spacelab flight. The second assembly, consisting of the igloo and pallets, will be delivered to NASA for the second Spacelab flight.

Payload requirements have changed as regards to the CMDS since the start of the program. In the beginning, much centralized computation was required by several experiments of each payload. Now, with the advance of electronics in the micro-processor field, users are building dedicated processors within their experiments. The role of the CDMS is that of an organizing and centralized data management function today rather than a centralized computation tool.

Development in the future is planned, but only after successful demonstration of the complete Space Transportation System performance and as the demand for more Spacelab flights materializes.

If such a user interest is forthcoming, then in the CDMS area, several improvments are envisaged. These improvements are:

- Computer — extension of the main memory
- Mass Memory — replacement of the MMU by a disk-like device
- Display System — additions to the vector/graphics capability
- RAU — simplified interface to experiment processors and equipment
- Multiplexer — improvement of the throughput of the link between the DPA and the HRM, the buffering and reclocking of the direct channels from the HDRR and the users to reduce error rates

These will be considered under the above constraints in a follow-on development program. The greatest boost that this program can have is a successful initial demonstration of the Shuttle, the TDRSS, and the Spacelab programs.

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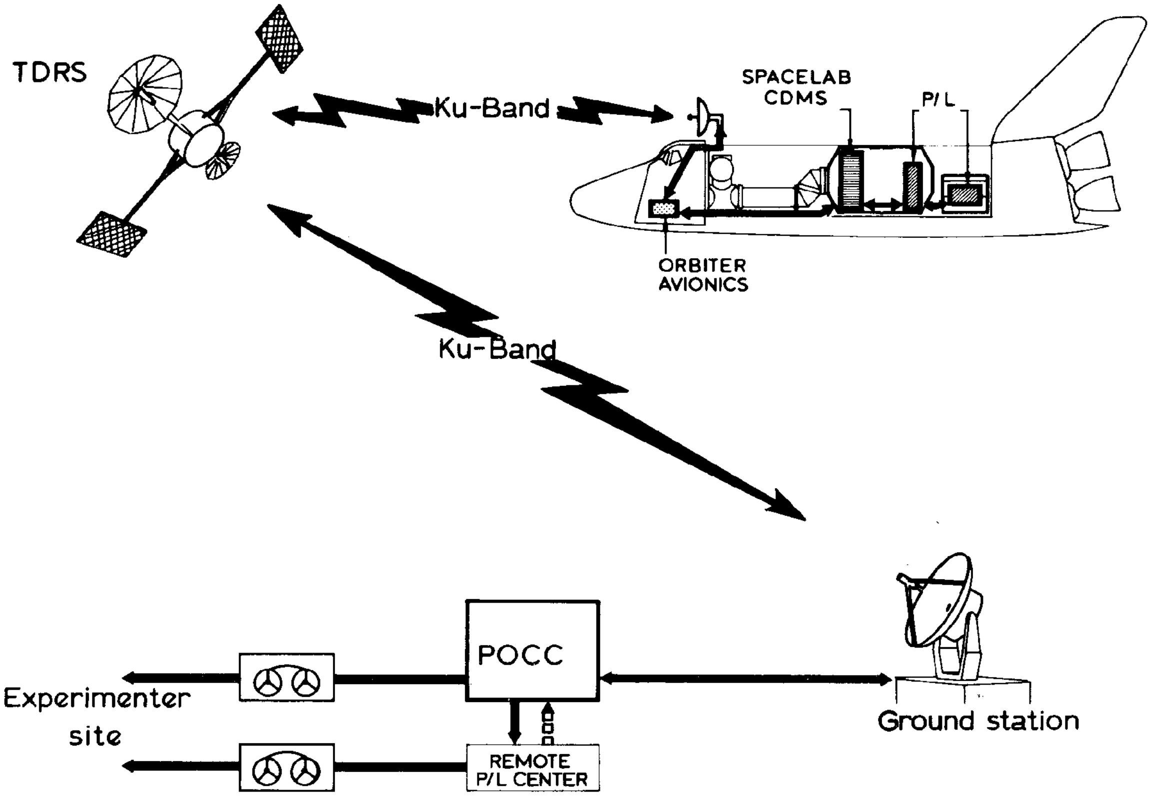


Figure 1. Overall Data Path

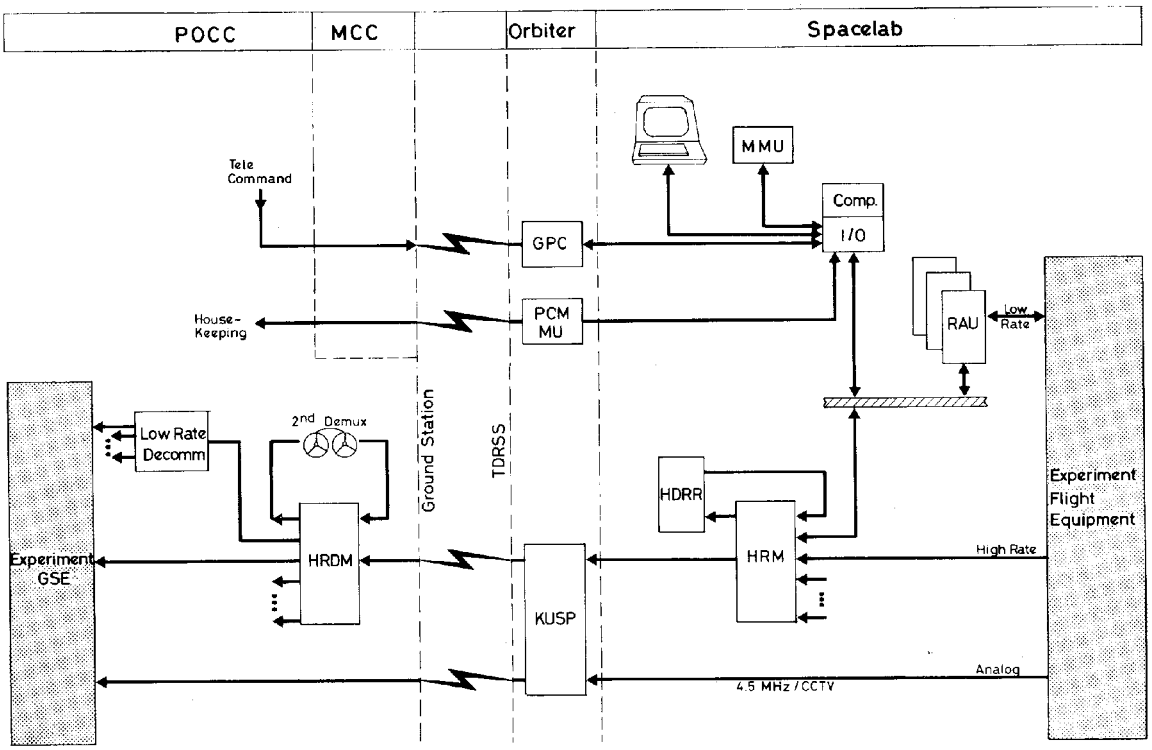
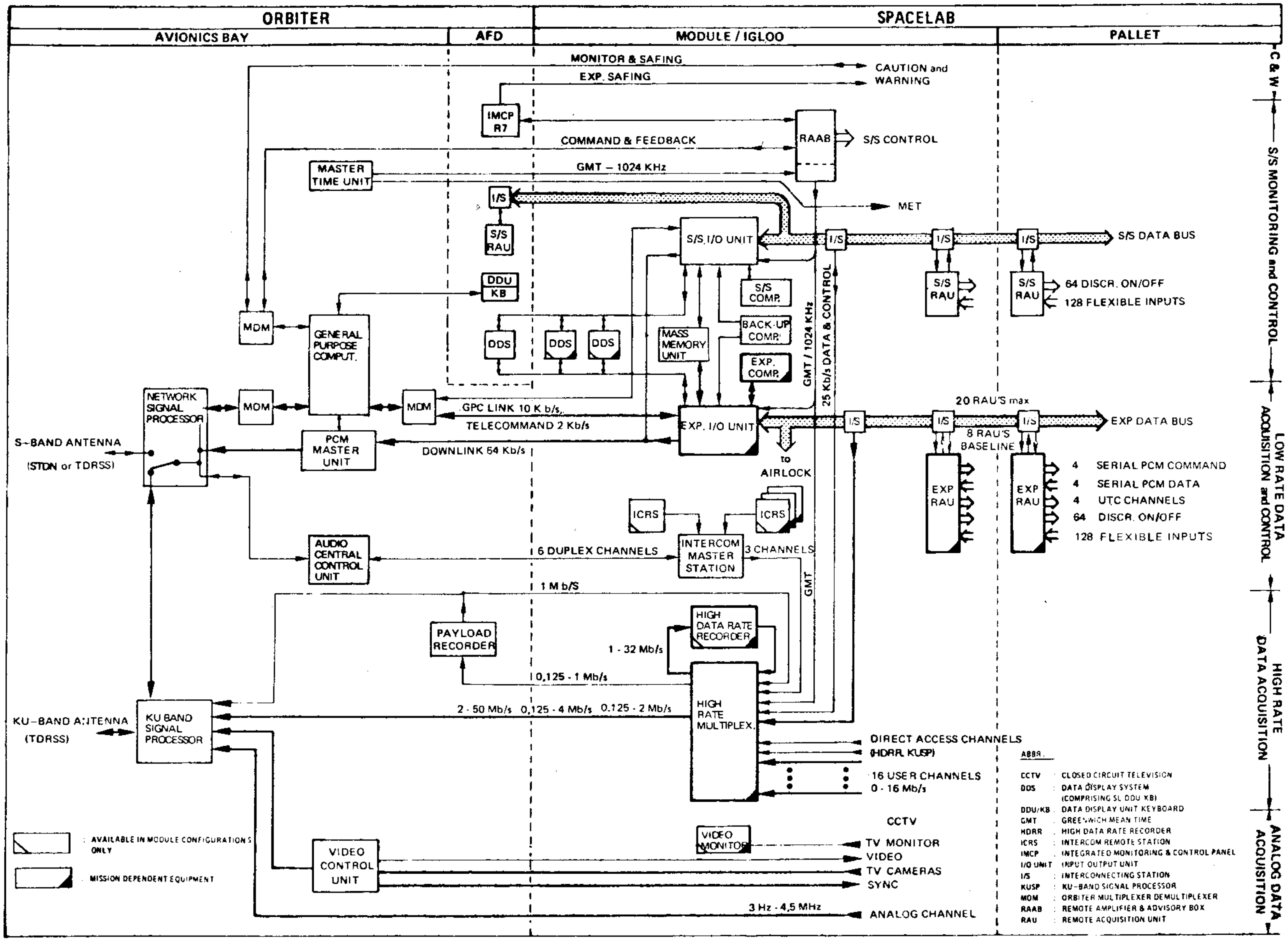
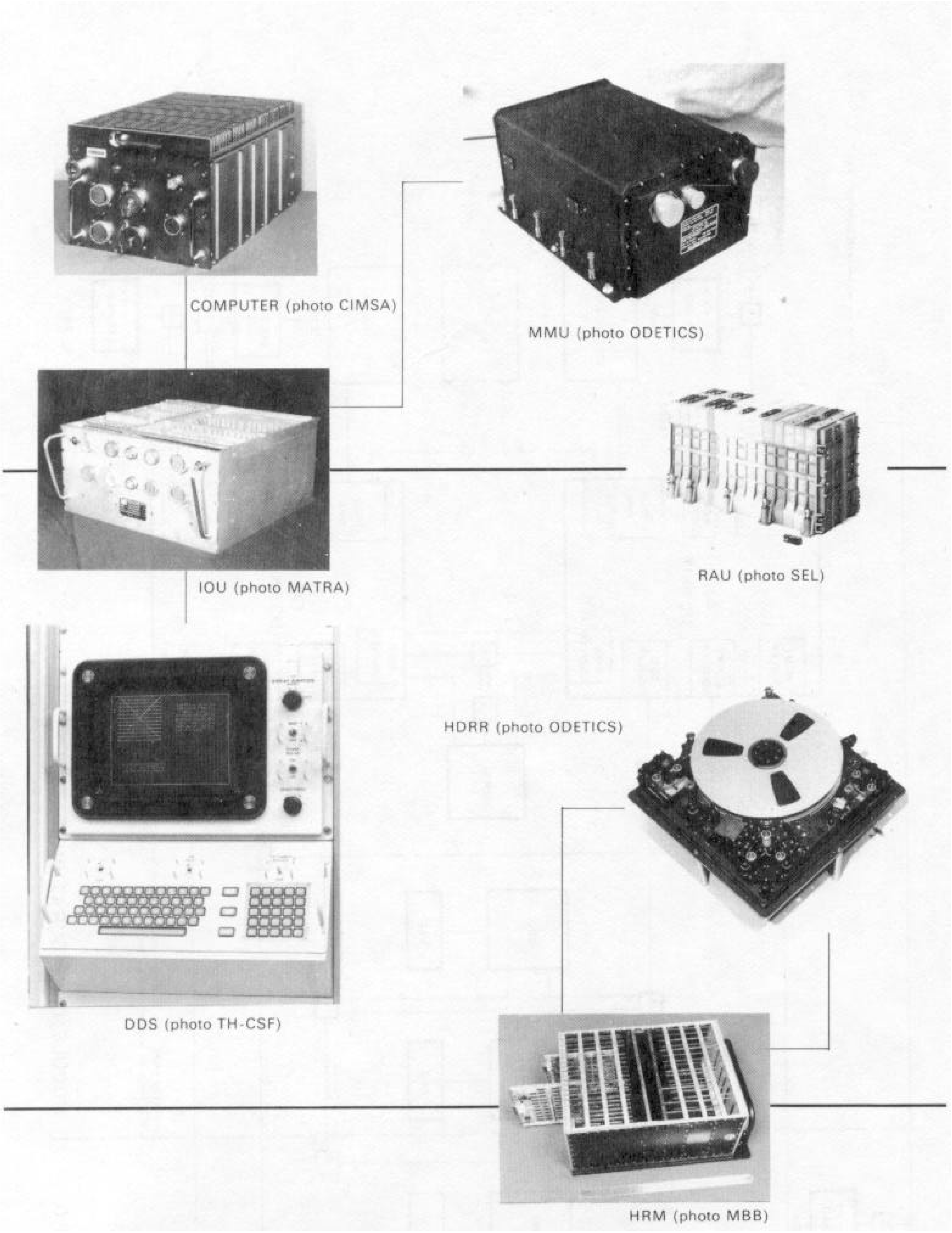


Figure 2. Overall Telecommunications Block Diagram



CDMS Block Diagram

Figure 3. Block Diagram of Spacelab CDMS and Related Orbiter Avionics



COMPUTER (photo CIMSA)

MMU (photo ODETICS)

RAU (photo SEL)

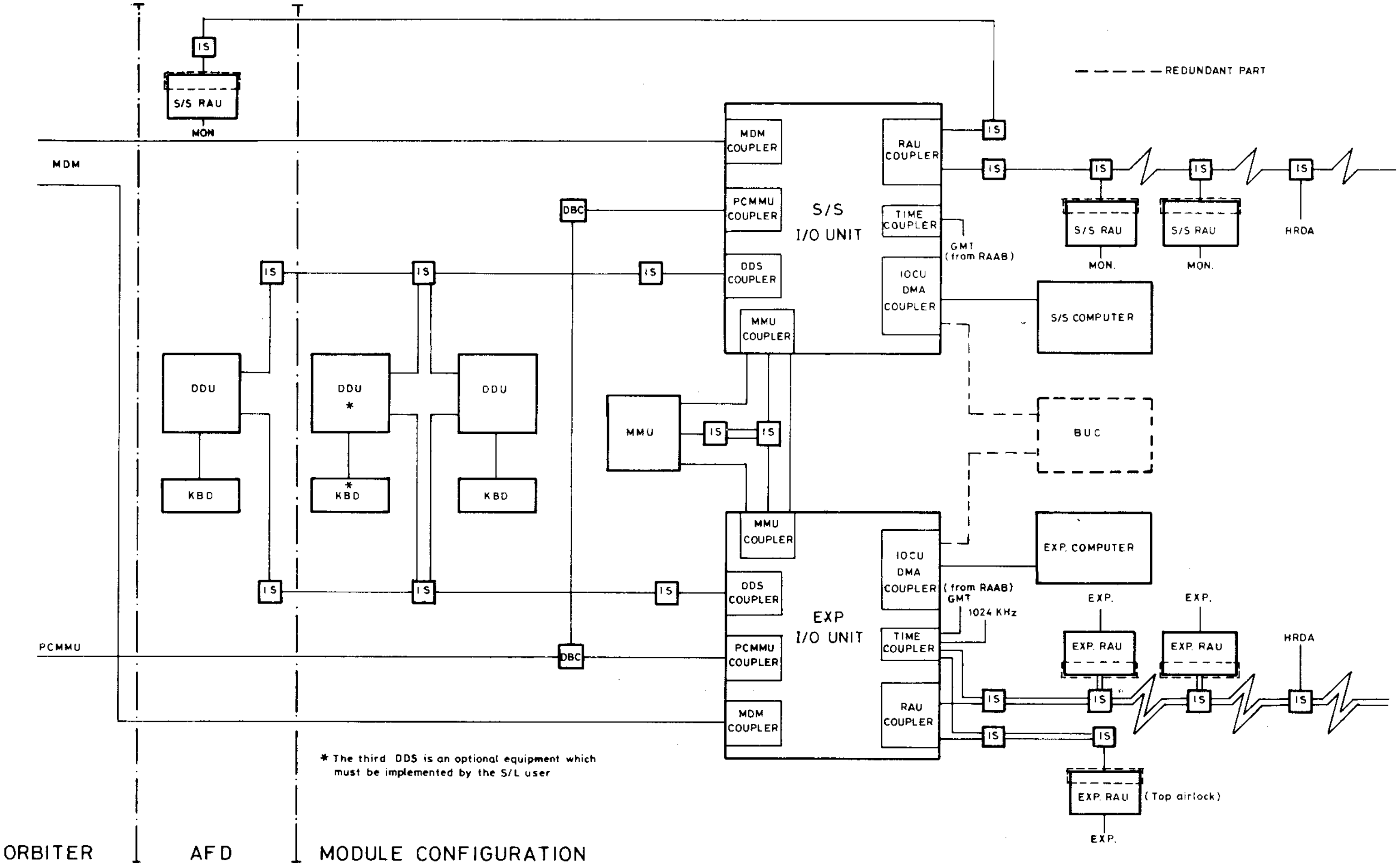
IOU (photo MATRA)

HDRR (photo ODETICS)

DDS (photo TH-CSF)

HRM (photo MBB)

Figure 4. CDMS Units



* The third DDS is an optional equipment which must be implemented by the S/L user

Figure 5. Data Processing Assembly

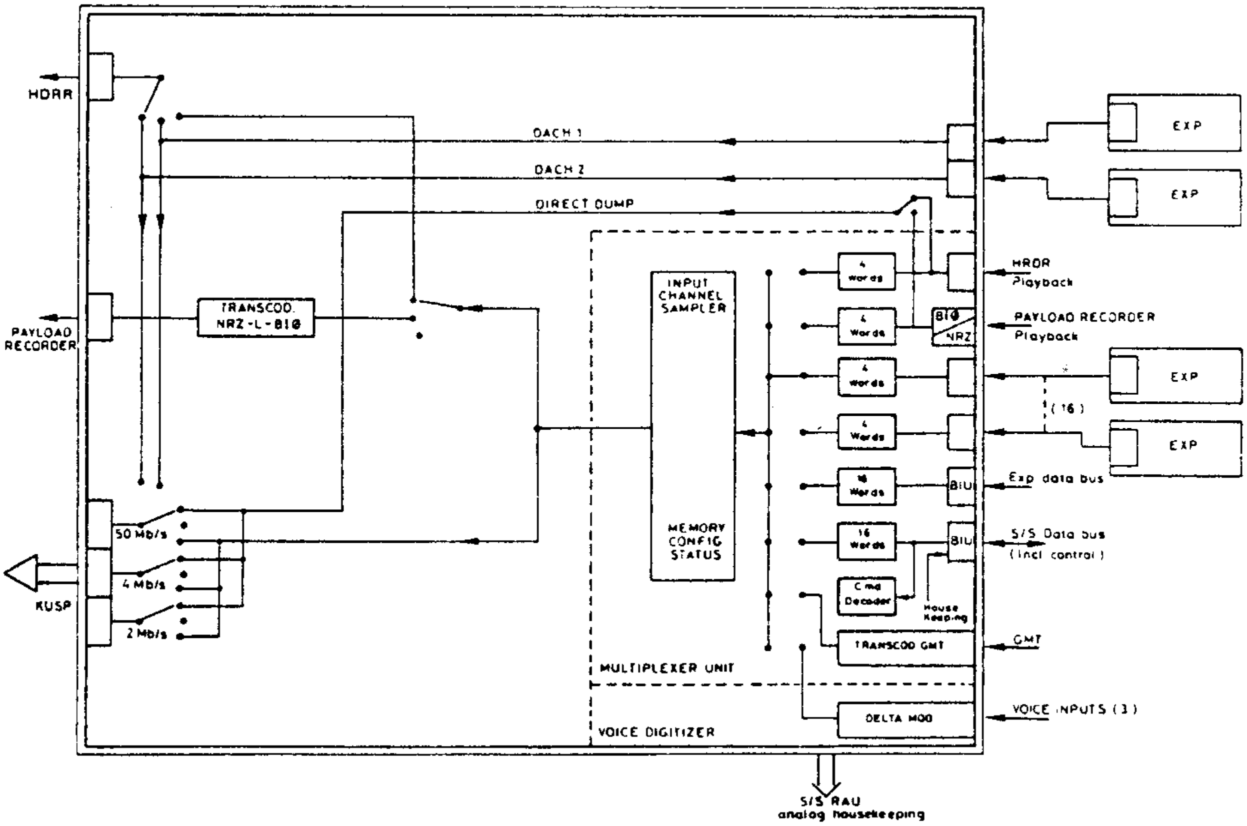


Figure 6. HRM Block Diagram

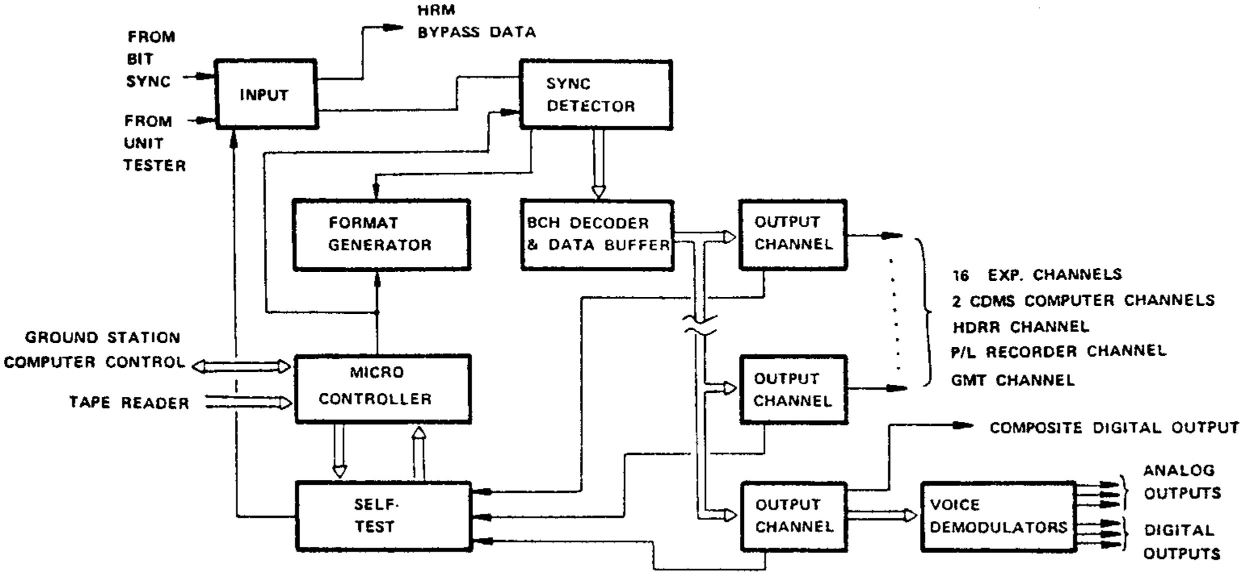


Figure 7. HRDM Block Diagram

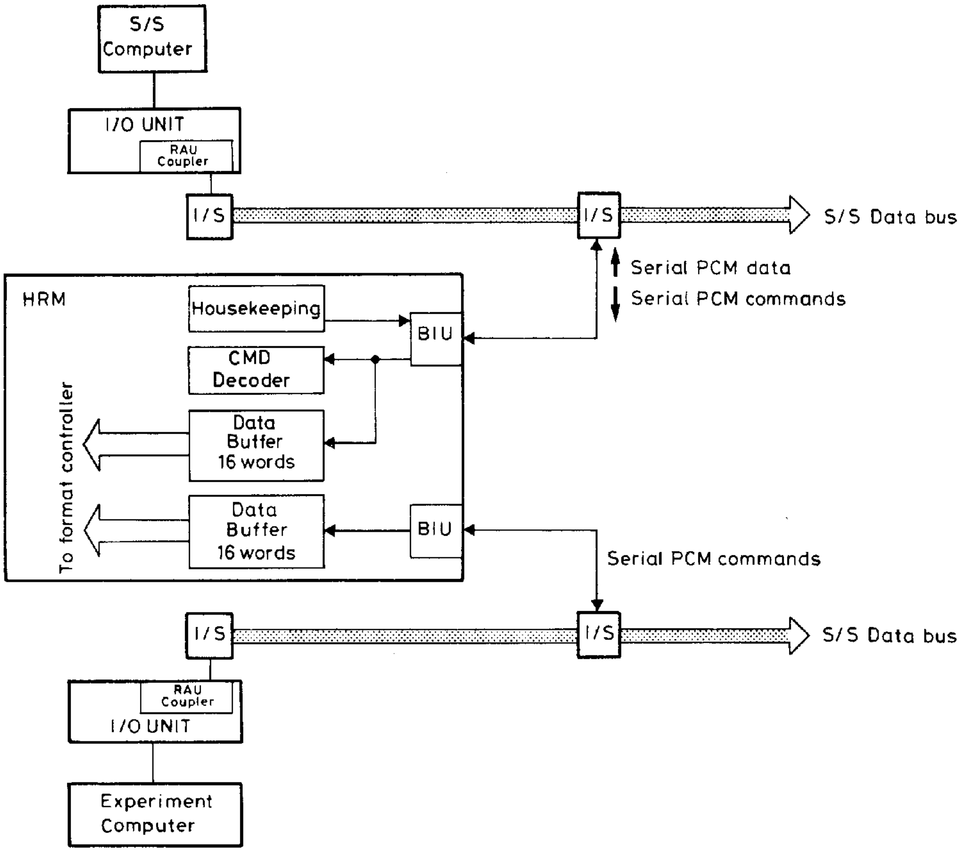


Figure 8. HRM/Computer Links

Table 1. Units of the CDMS and Their Functions

Unit	No.	Function
Subsystem and Experiment Computer (SSC/EXC	2(+1)	Arithmetic/Storage/Realtime Control.
Input/Output Unit (IOU)	2	Databus and peripheral controller
Experiment & Subsystem Data Bus	2(+ 2)	Data acquisition and distribution of commands.
Keyboard (kB)	3	Crew commands Man/machine Interface
Data Display Unit (DDU)	3	Display data
Mass Memory Unit (MMU)	1	Storage of programmes and data.
High Data Rate Recorder (HDRR)	1	Digital data storage during interrupted TDRSS communications.
High Rate Multiplexer (HRM)	1	Time division multiplexing of digital serial data.
Remote Acquisition Unit (SS RAU/EXP RAU)	9/≤21	Peripheral data bus input/output unit.